Installation Integrity Measurement for Various Sensors

Morrison R. Burns, Jr./EB22
205–544–2556

Analysis and Measurement Services Corporation is working with NASA/MSFC under a Small Business Innovation Research agreement, phase II, to develop techniques for measuring the installation integrity of various sensors. The main effort of this contract has been to advance the use of the loop-current step-response technique to measure the installation integrity and dynamic response characteristics of a thermocouple, as installed in composite materials. Sensors being studied include various types of thermocouples, strain gauges, thermistors, platinum resistance thermometers, and other resistance temperature devices.

The loop-current step-response test is based on heating the sensor internally by applying a small electric current to its leads. For thermocouples, the current is applied for a few seconds and removed; thermocouple output is then recorded as it cools to ambient temperature. The output is an exponential transient that can be analyzed to yield the response time of the installed thermocouple, as well as determine bond integrity. This technique can test sensors as they are installed in the field. Because it is not necessary to remove sensors being tested, loop-current step-response testing is very useful when inspecting sensors installed in inaccessible locations. Access to the sensor's leads is all that is required; the actual sensor can be a significant distance from the testing site.

For the Solid Propulsion Integrity Program, hundreds of thermocouples have been tested, both in the laboratory and in the field, to aid in program efforts to test new materials for suitability as nozzle material in solid rocket motor nozzles. Numerous thermocouples have been installed at varying locations and depths in a small solid rocket motor test article to determine the temperature profile of the nozzle. Thermocouple time response and installation integrity have been critical factors in the Solid Propulsion Integrity Program testing.

A typical, normalized loop-current step-response transient test is shown in figure 108. While the feasibility of using the loop-current step-response technique was demonstrated during phase I of this effort, phase II has shown conclusively that this type of testing is a highly useful and very practical tool for testing thermocouples installed in solid materials.

Extensive laboratory testing on strain gauges has illustrated the practicality of using the loop-current step-response technique to determine bond integrity of strain gauges. For comparison, self-heating index tests

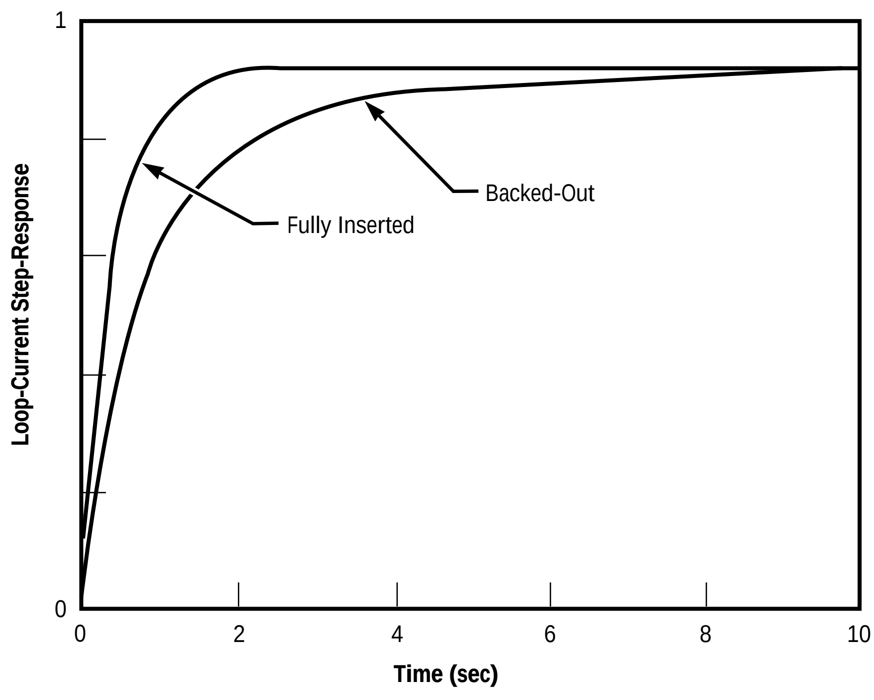

FIGURE 108.—Normalized loop-current step-response transients showing the difference in response time between a fully inserted and a backed-out thermocouple (fully inserted then backed out of the hole by a small amount, leaving a void). Thermocouples were installed in sample nozzle material and tested at room temperature.

were also performed; the results were consistent with the loop-current step-response tests. While Analysis and Measurement Services has performed some strain-gauge field testing at MSFC—and results have been encouraging—the testing has been too small-scale to show anything other than feasibility.

Several commercially available thermistors have been loop-current step-response tested. Initial results gave response times that were nonconservative when compared with conventional plunge test results. This effect was attributed to the variation in power provided to the thermistors during the tests, resulting in a self-catalytic effect. When minor modifications were made to test equipment to eliminate this problem, the retested results were comparable to the standard plunge test results, indicating that the loop-current step-response test method can be used effectively for testing the installation integrity of thermistors.

The bond quality of the six surface-mounted platinum resistance thermometers currently used on each space shuttle main engine has been a concern to NASA. In view of this, Analysis and Measures Services purchased several flight-type platinum resistance thermometers (nonflight-qualified) for laboratory testing. Both loop-current step-response and self-heating index tests were performed. Results indicated good correlation between the two tests, and good bonds were detectable from partial bonds. Some field testing has also been performed on several flight platinum resistance thermometers. Testing to date has shown the feasibility of using the loop-current step-response technique, but more field testing will be necessary to obtain reliable results.

Because the loop-current step-response test pulses the platinum resistance thermometer with a small current, some concern has arisen about its impact on calibration. (A normal test will pulse 15 to 20 milliamperes of current through the thermometer.) In one test, a new platinum resistance thermometer was calibrated, then repeatedly subjected to a 60-milliampere current pulse for 24 hours, and finally recalibrated. Results indicated a calibration shift of less than 0.2 °F, which suggests that a normal loop-current step-response test will not appreciably affect calibration.

The loop-current step-response technique has proven to be a very valuable diagnostic tool for various sensors. Its only drawback is that it cannot give reliable results for a single sensor installation. Reliability of the loop-current step-response test increases with the number of sensor installations being tested. This technique is especially useful for testing large numbers of sensors with similar installations, when accessibility to the sensor is not needed.

Hashemian, H.M.; Mitchell, D.W.; Shell, C.S.; and Farmer, J.P. July 1993. Improved Temperature Measurement in Composite Material for Aerospace Applications. Final Report, Small Business Innovation Research, Phase I. Contract NAS8–39814, Report NASA9306R0.

Sponsor: Small Business Innovation Research

Industry Involvement: Analysis and Measurement Services Corporation

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